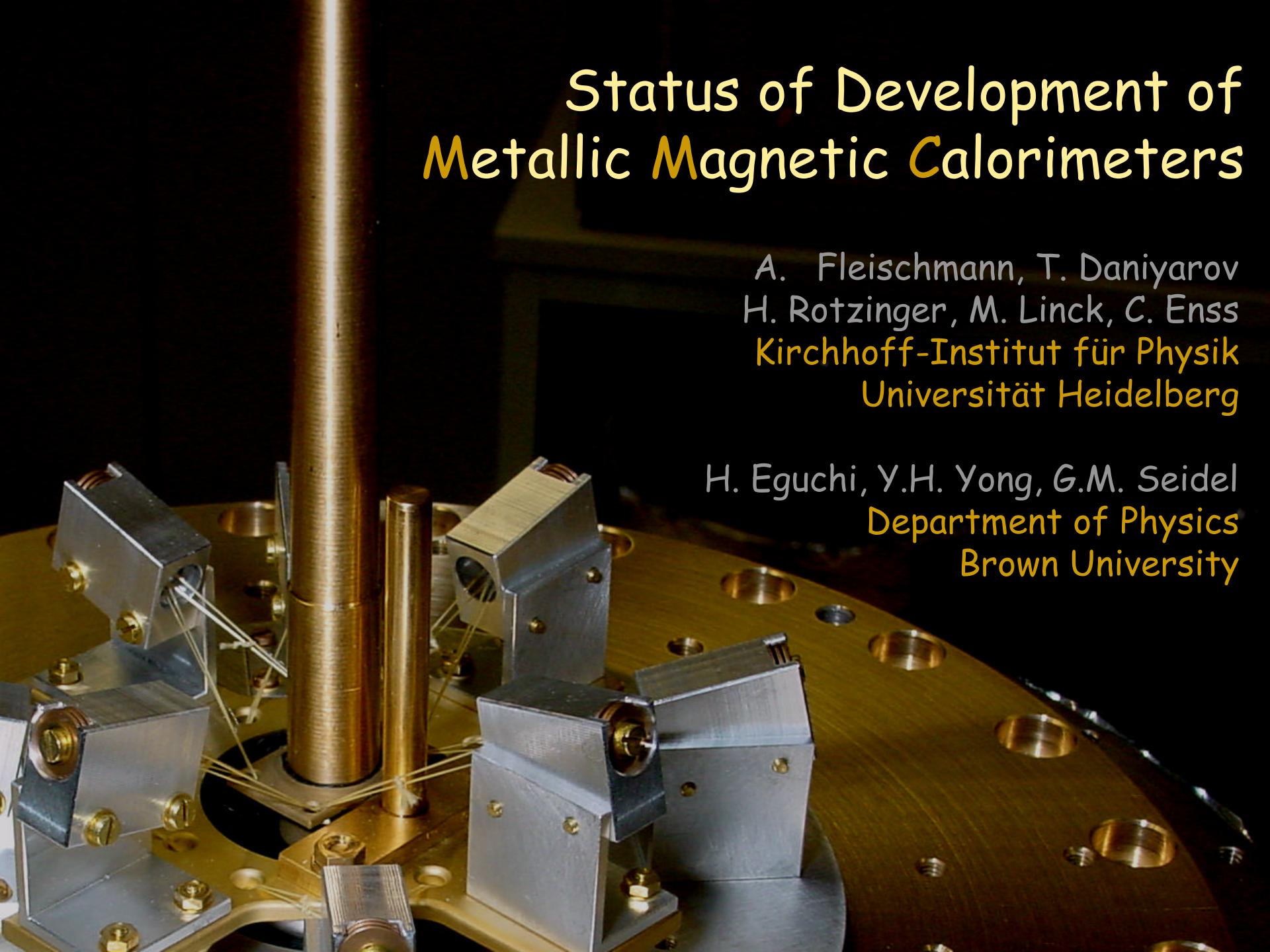


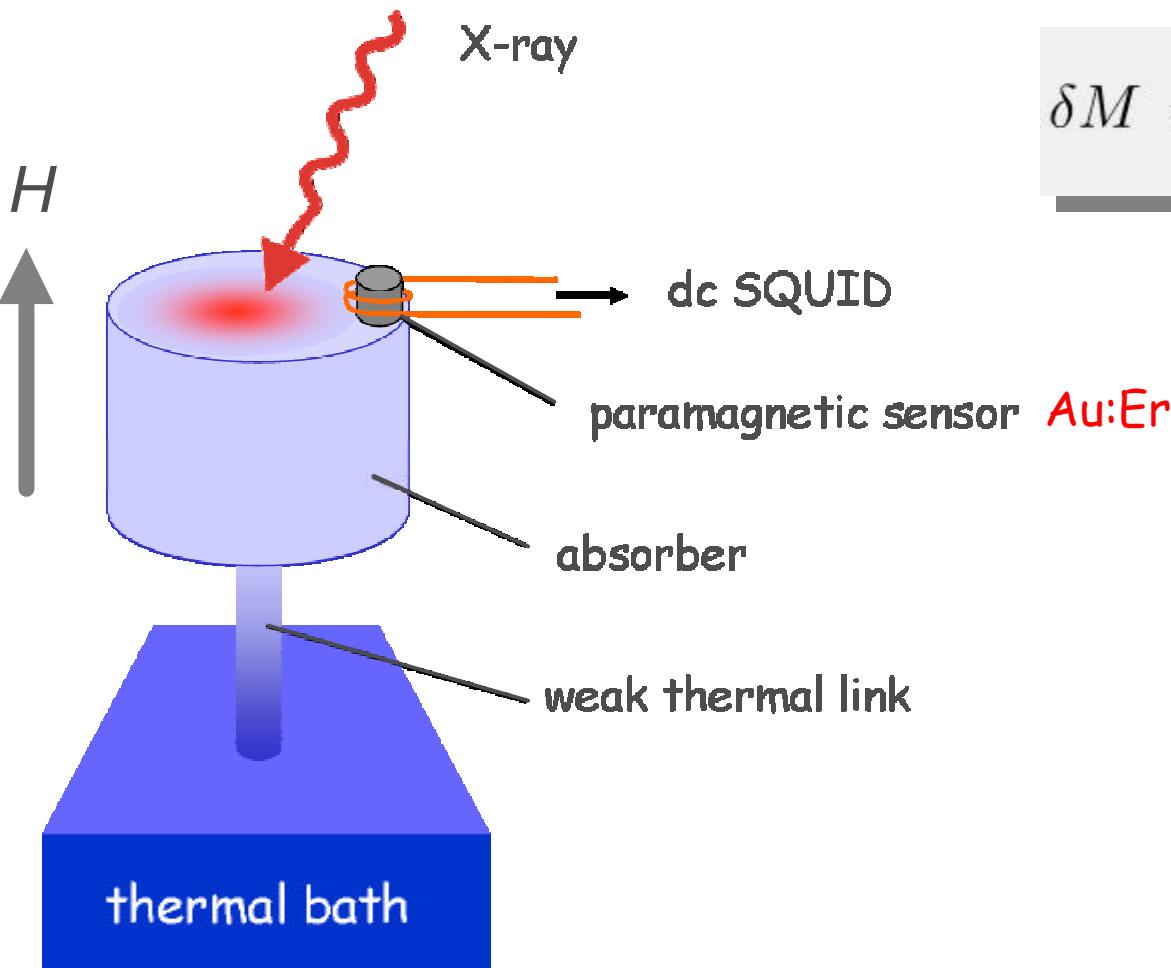
# Status of Development of Metallic Magnetic Calorimeters

A. Fleischmann, T. Daniyarov  
H. Rotzinger, M. Linck, C. Enss  
Kirchhoff-Institut für Physik  
Universität Heidelberg

H. Eguchi, Y.H. Yong, G.M. Seidel  
Department of Physics  
Brown University



# Metallic Magnetic Calorimeter



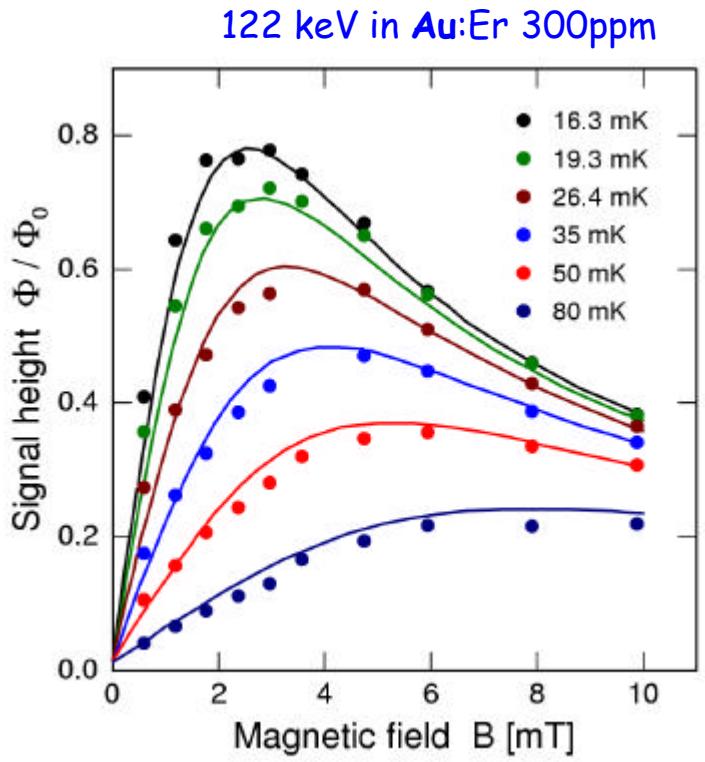
$$\delta M = \frac{\partial M}{\partial T} \delta T = \frac{\partial M}{\partial T} \frac{E_\gamma}{C_{\text{tot}}}$$

$$\tau = \frac{C_{\text{tot}}}{G}$$

# Calorimeter Signal

$$\delta\Phi_S = f(r, h) \frac{\partial M}{\partial T} \frac{1}{C_{\text{tot}}} \delta E$$

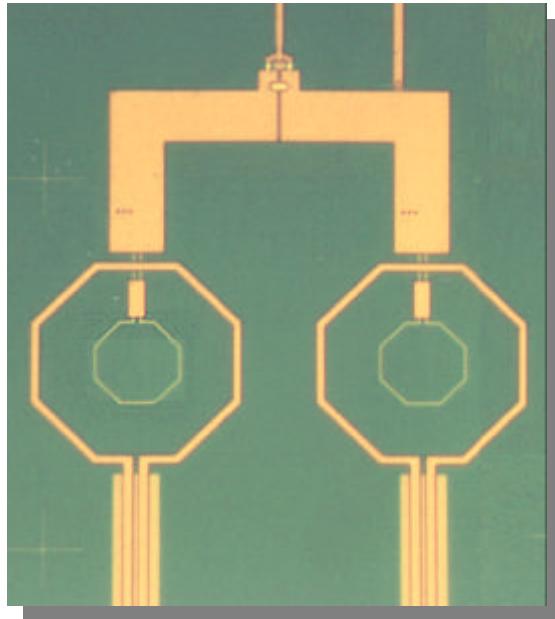
- satisfying **agreement** of theory and experiment
- signal size can be **predicted!**



Resolution of optimized detector:

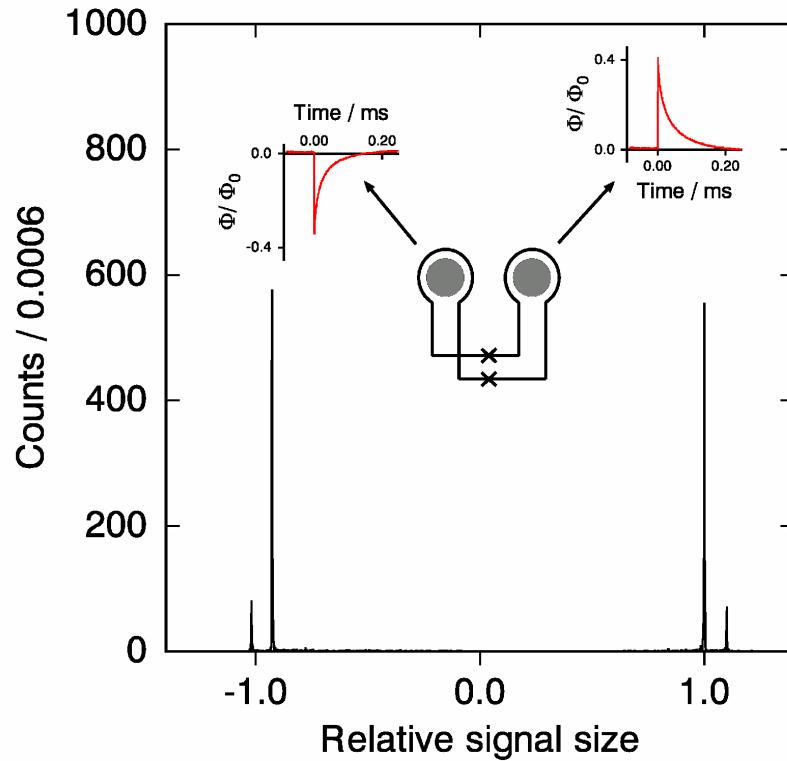
$$\Delta E_{\text{FWHM}} \simeq 2.36 \sqrt{4k_B C_a T^2} \sqrt{2} \left( \frac{\tau_0}{\tau_1} \right)^{1/4}$$

# Gradiometer With Two Sensors: Two-Pixel Detector



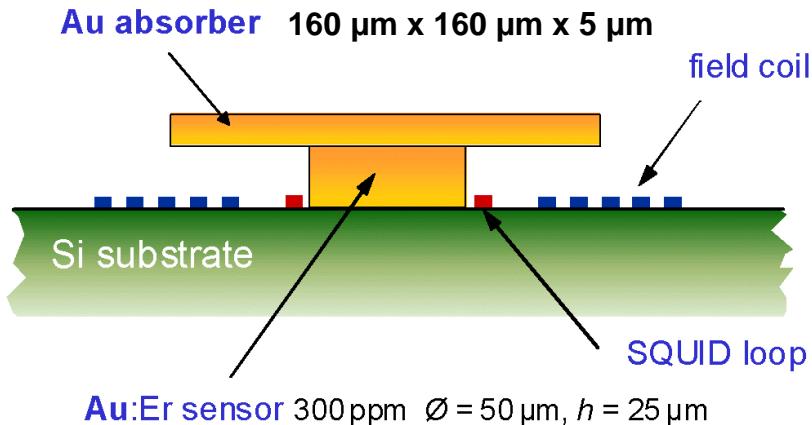
commercial SQUID chip

M.B. Ketchen, IBM 1992



performance of pixels almost  
identical

# Latest MMC Detector

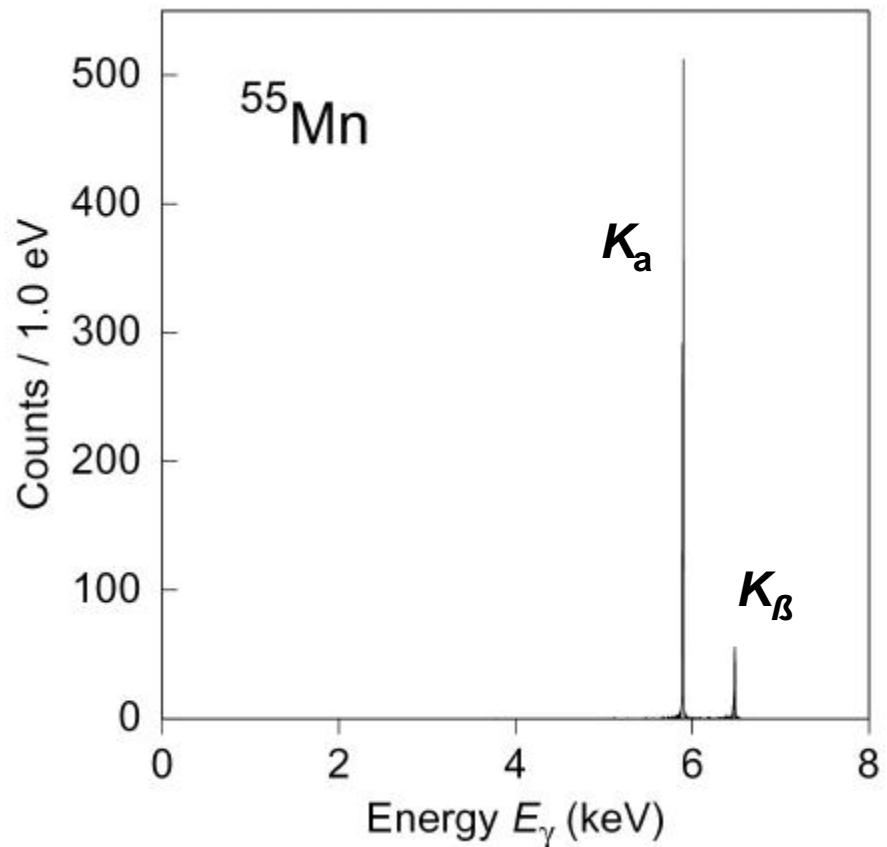


two Au:Er 300 ppm sensors

Gold absorber:  $160 \times 160 \times 5 \mu\text{m}^3$

Heat capacity corresponds to a  
Bi absorber of  $250 \times 250 \times 28 \mu\text{m}^3$

→ clean spectrum

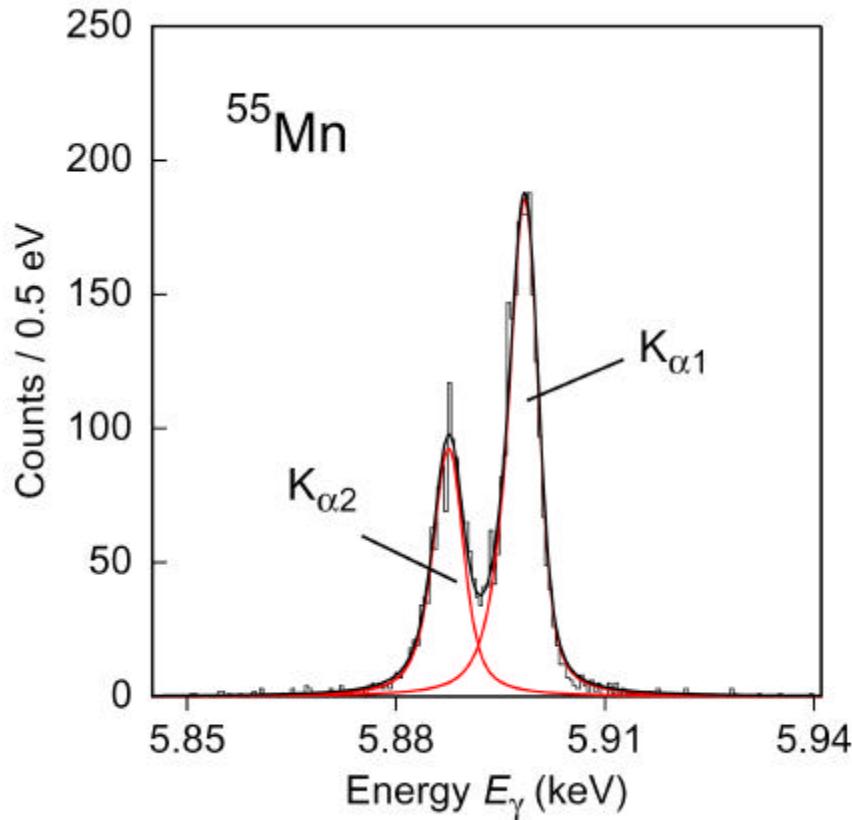
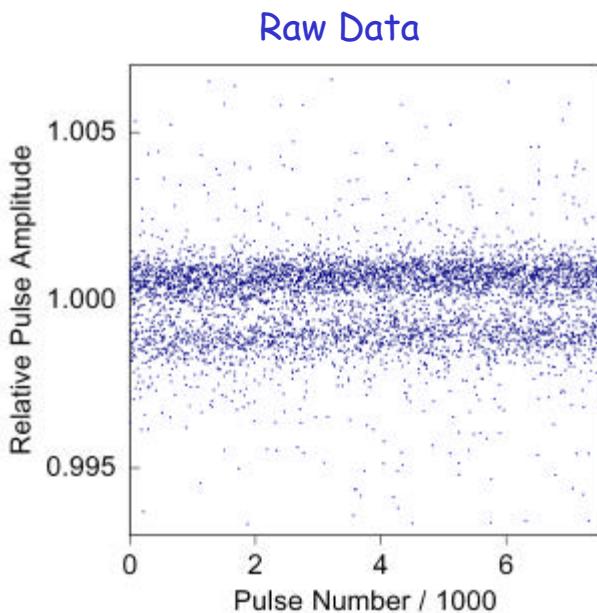


# Resolution: $K_{\alpha}$ -Line $^{55}\text{Mn}$

two Au:Er 300 ppm sensors

Gold absorber:  $160 \times 160 \times 5 \mu\text{m}^3$

Heat capacity corresponds to a  
Bi absorber of  $250 \times 250 \times 28 \mu\text{m}^3$



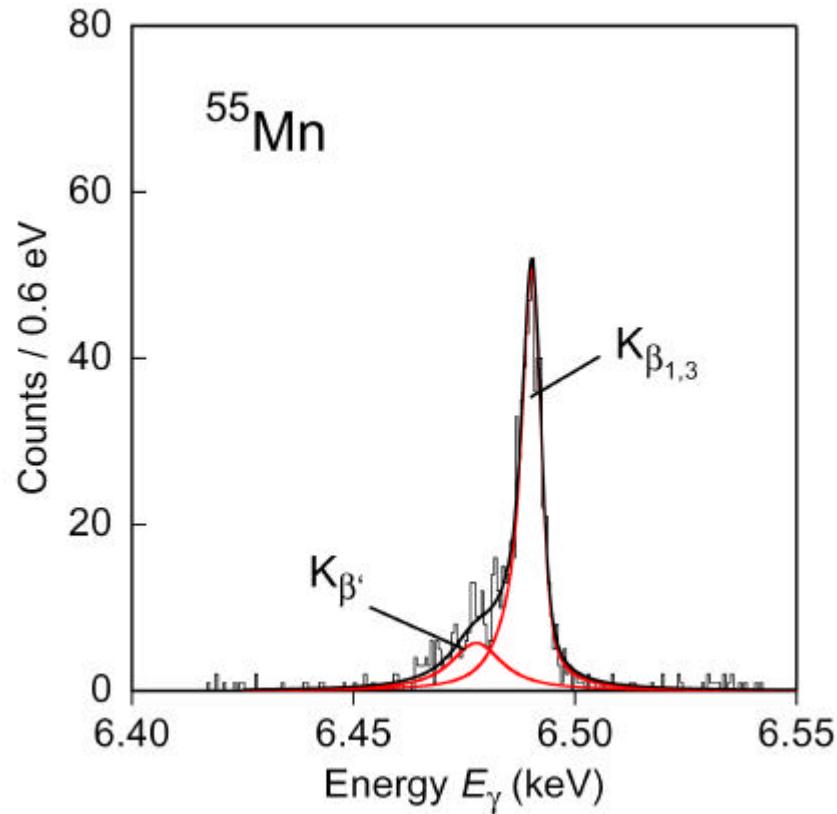
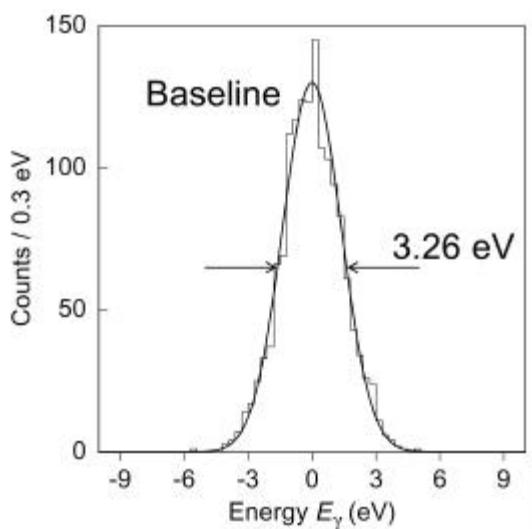
energy resolution 3.4 eV

# Resolution: K<sub>B</sub>-Line <sup>55</sup>Mn

two Au:Er 300 ppm sensors

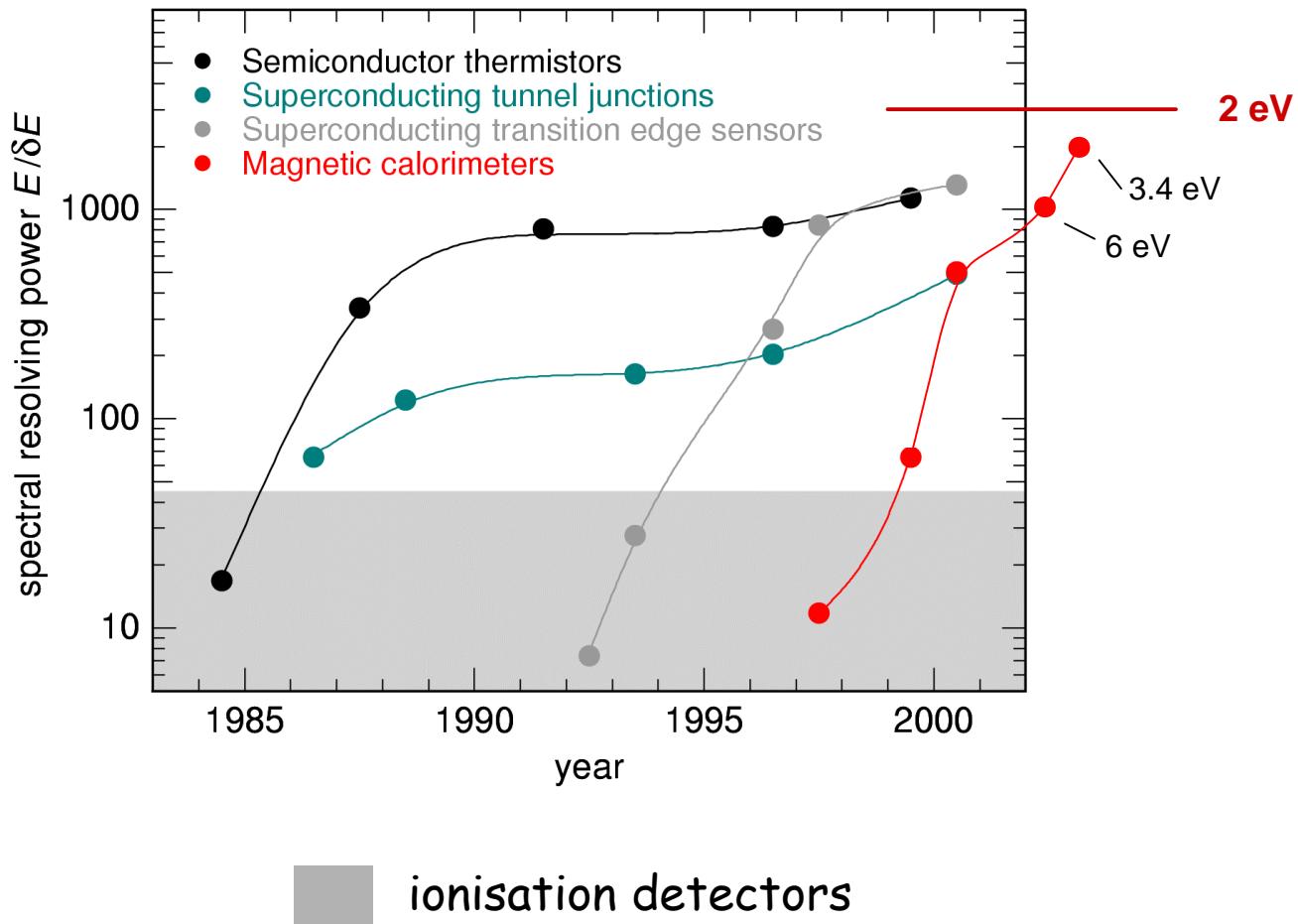
Gold absorber:  $160 \times 160 \times 5 \mu\text{m}^3$

Heat capacity corresponds to a Bi absorber of  $250 \times 250 \times 28 \mu\text{m}^3$

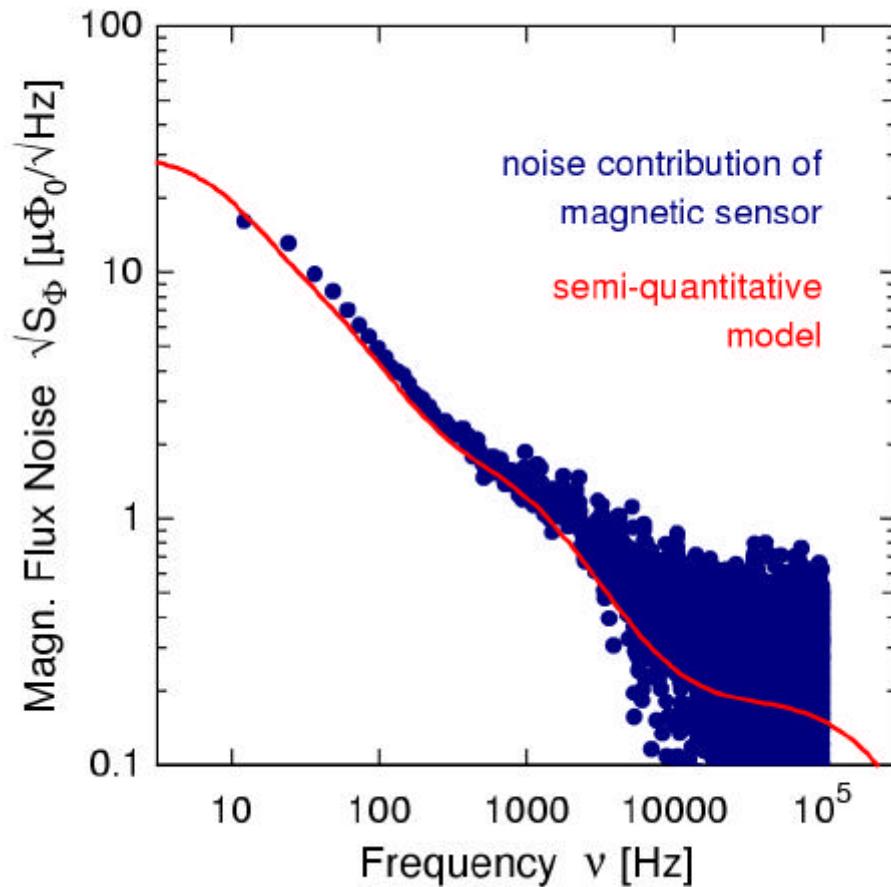


energy resolution 3.4 eV

# $E/dE$ at 6 keV



# No Unknown Noise



# Predicted Resolution for Different Detectors

Resolution:

$$\Delta E_{\text{FWHM}} \simeq 2.36 \sqrt{4k_B C_a T^2} \sqrt{2} \left( \frac{\tau_0}{\tau_1} \right)^{1/4}$$

Energy range: 1 ... 6 keV

$T = 50 \text{ mK}$ ,  $t_0 = 10^{-6} \text{ s}$ ,  $t_1 = 10^{-4} \text{ s}$

$250 \times 250 \times 5 \mu\text{m}^3$ , Bi absorber

Au:Er 900 ppm sensor,  $\varnothing 35 \mu\text{m}$ ,  $h = 14 \mu\text{m}$

Energy range: 0.25 ... 0.6 keV

$T = 50 \text{ mK}$ ,  $t_0 = 10^{-6} \text{ s}$ ,  $t_1 = 10^{-4} \text{ s}$

$120 \times 120 \times 0.5 \mu\text{m}^3$ , Bi absorber

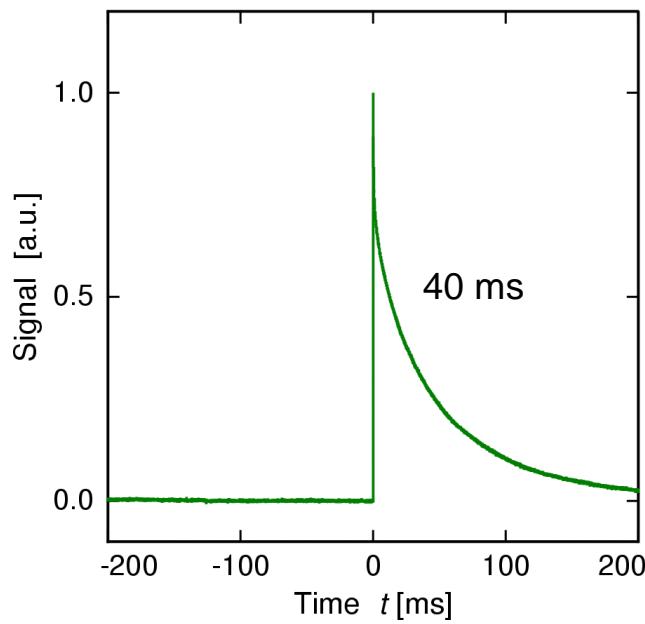
Au:Er 900 ppm sensor,  $\varnothing 20 \mu\text{m}$ ,  $h = 8 \mu\text{m}$

$$\rightarrow \Delta E_{\text{FWHM}} = 0.7 \text{ eV}$$

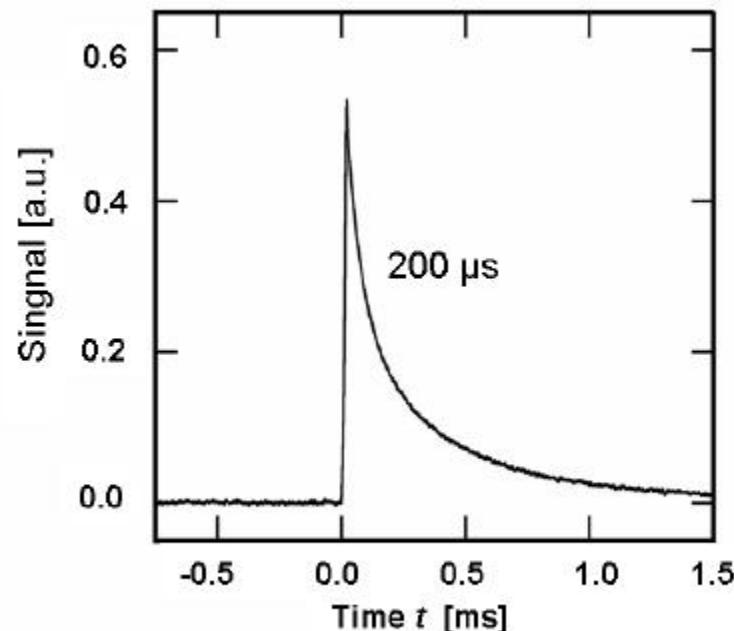
$$\rightarrow \Delta E_{\text{FWHM}} = 0.1 \text{ eV}$$

# Thermalization

Sensor bonded with vacuum grease to Si  
Heat capacity  $1.2 \times 10^{-12} \text{ J/K}$

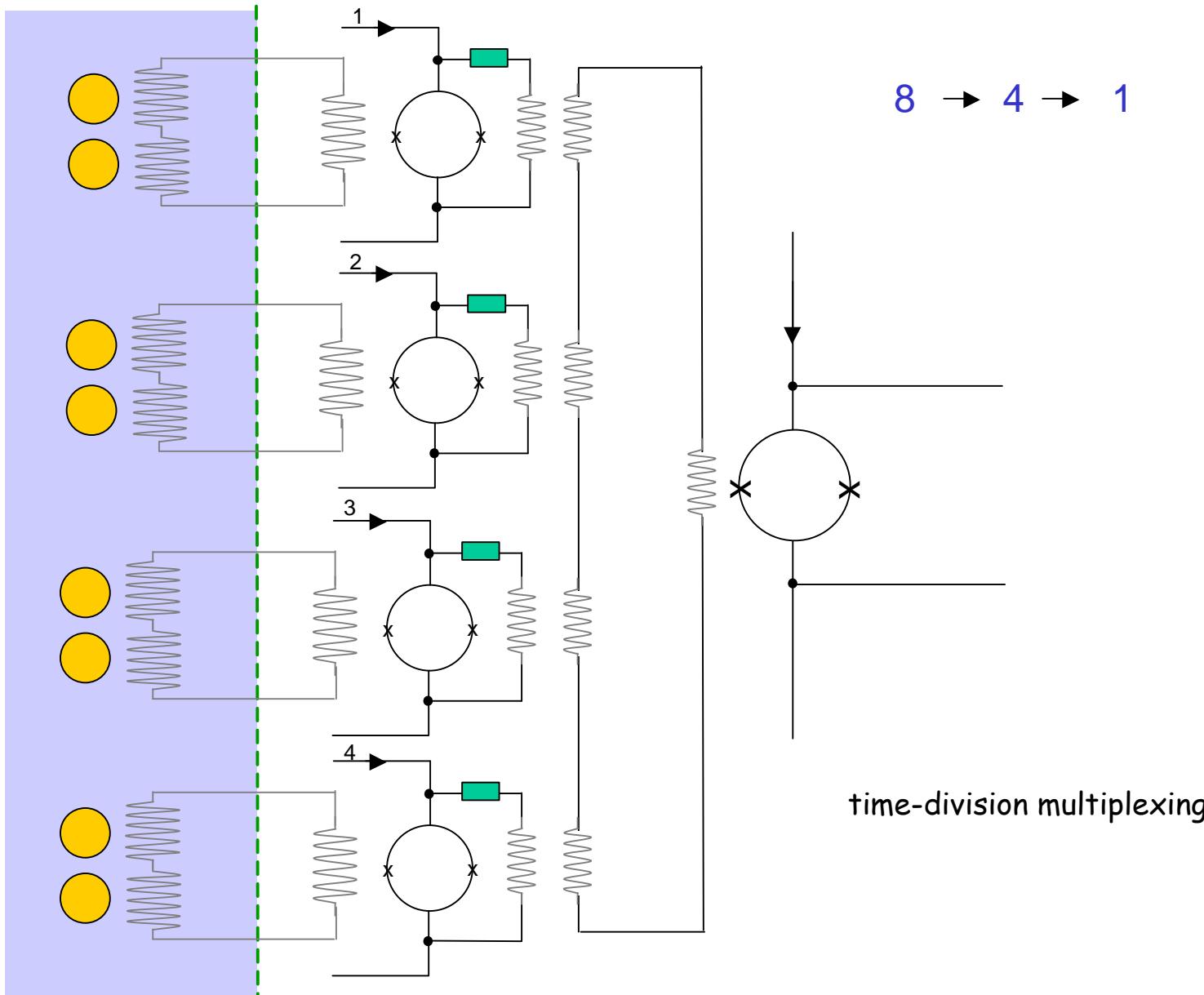


Spot welded detector  
Heat capacity  $10^{-9} \text{ J/K}$



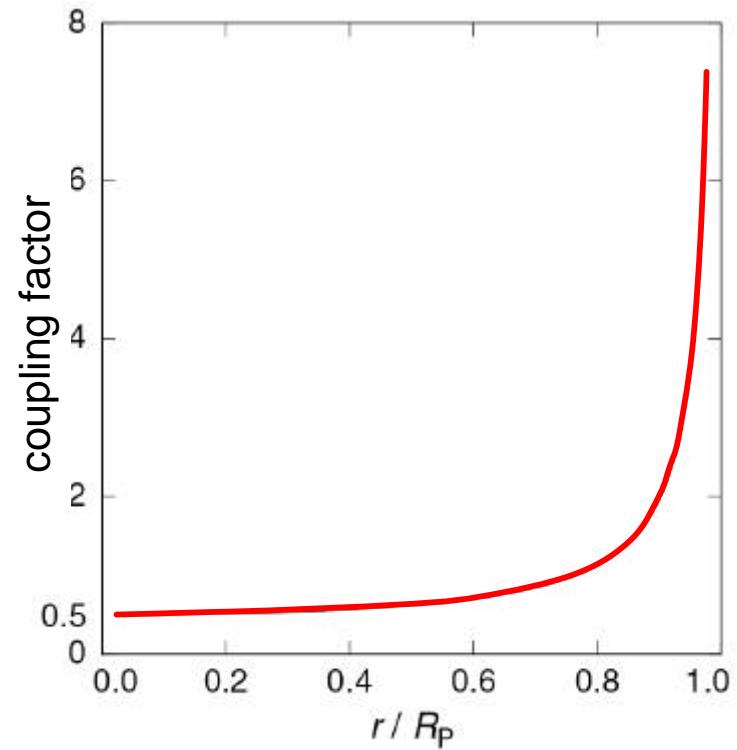
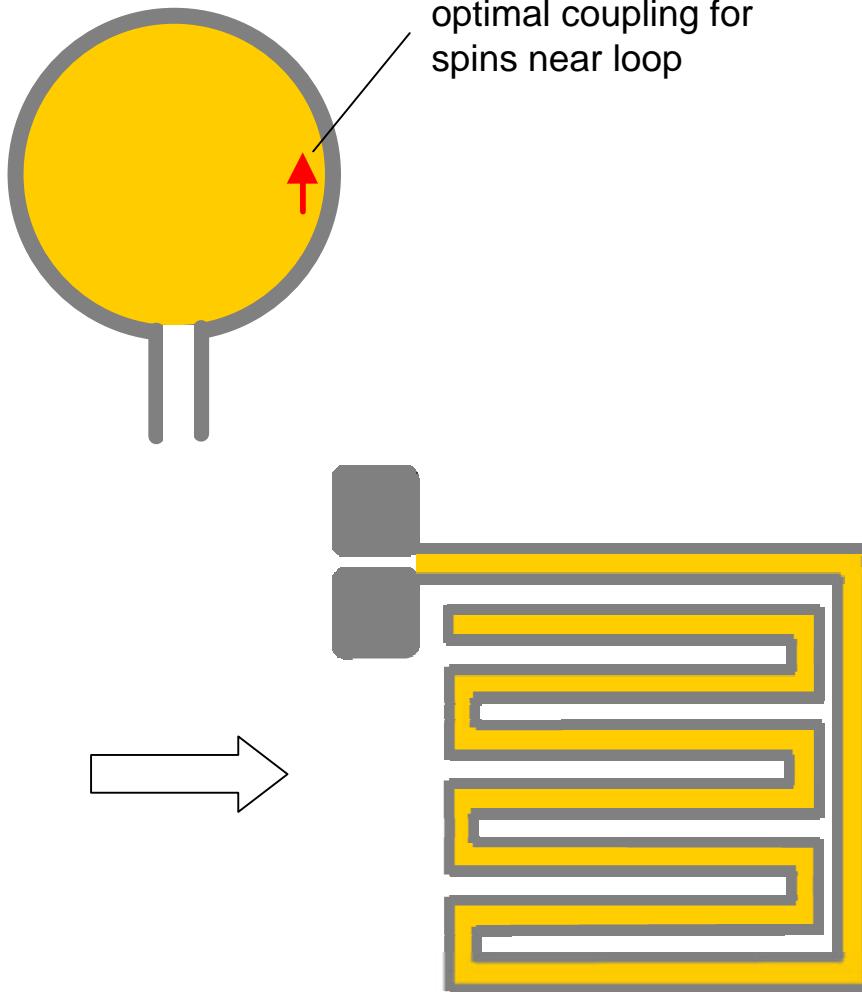
- magnetic calorimeters can be made very fast
- cost in terms of resolution is a factor  $\left(\frac{\tau_0}{\tau_1}\right)^{1/4}$

# MMC - Arrays

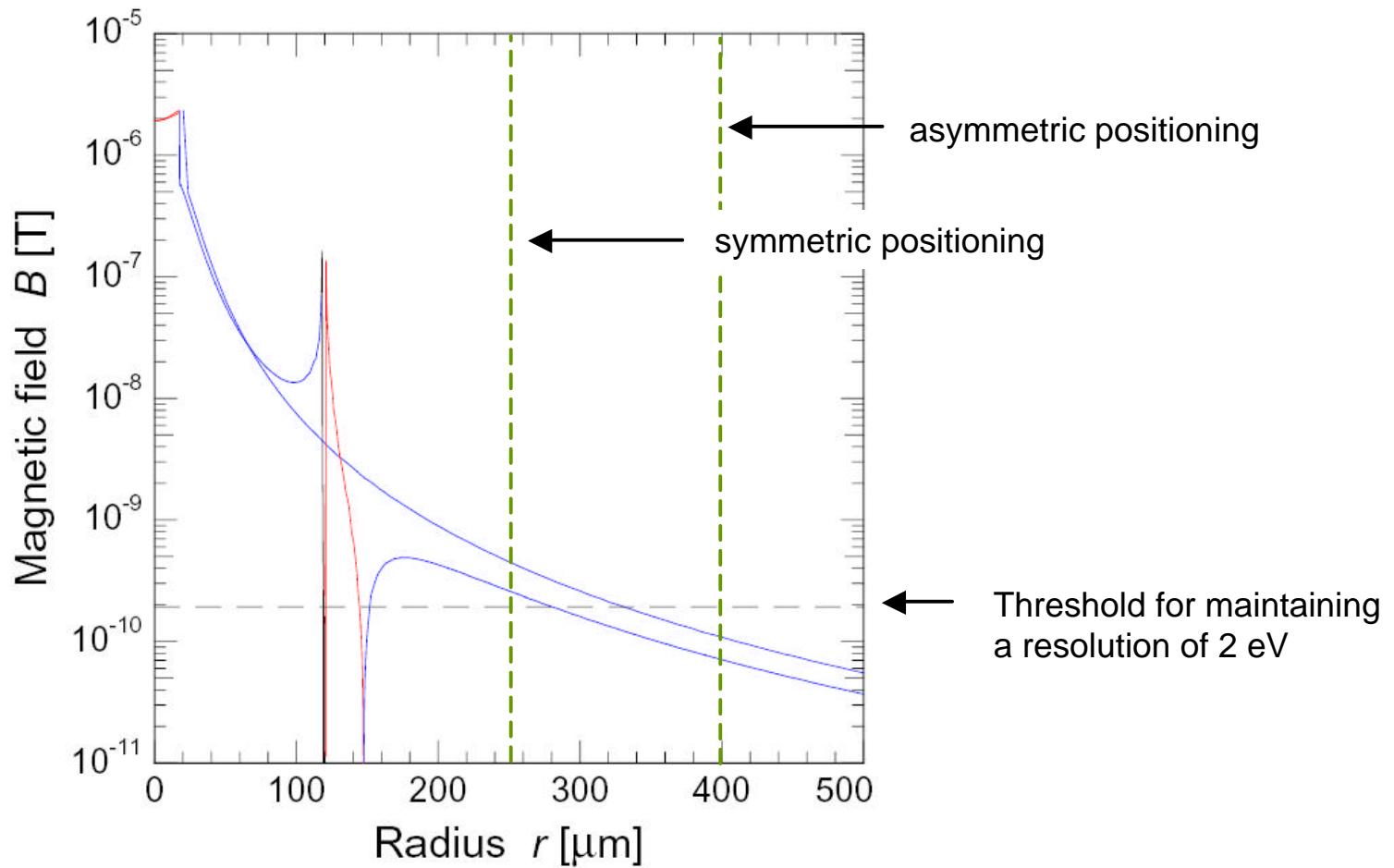


# Optimal Coupling

coupling depends on spin position

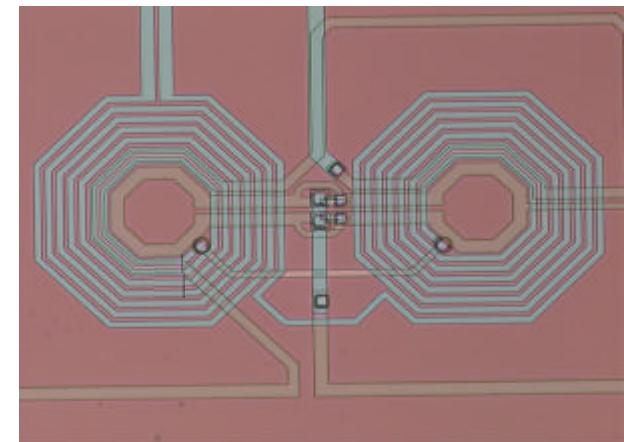


# Magnetic Cross Talk



# Outlook

- improved electronics
- optimized SQUIDs } IPHT Jena
- integrated detectors → SAO  
Simon Bandler  
Suzanne Romaine  
Hiroshi Eguchi
- arrays → ?



## Favorable properties of magnetic calorimeters for X-ray detection

- no unknown noise sources
- energy resolution  $dE/E$  of better than  $3 \times 10^{-4}$  is expected at 6 keV
- large mass absorbers are possible → high quantum efficiency
- compatible with micro fabrication techniques and TES multiplexing schemes
- gradiometer configuration → no thermal cross talk → direct deposition on Si